

# ***TOF rate studies and ... else***

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M. Rossella, R. Nardo')**

# Outline

1. HV crate refurbishing
2. A backup solution for TOF in case **B** fields in the MICE Hall is out of control
3. The rate effect problem
  - Conclusions

# 1. SY527 HV crate refurbishing

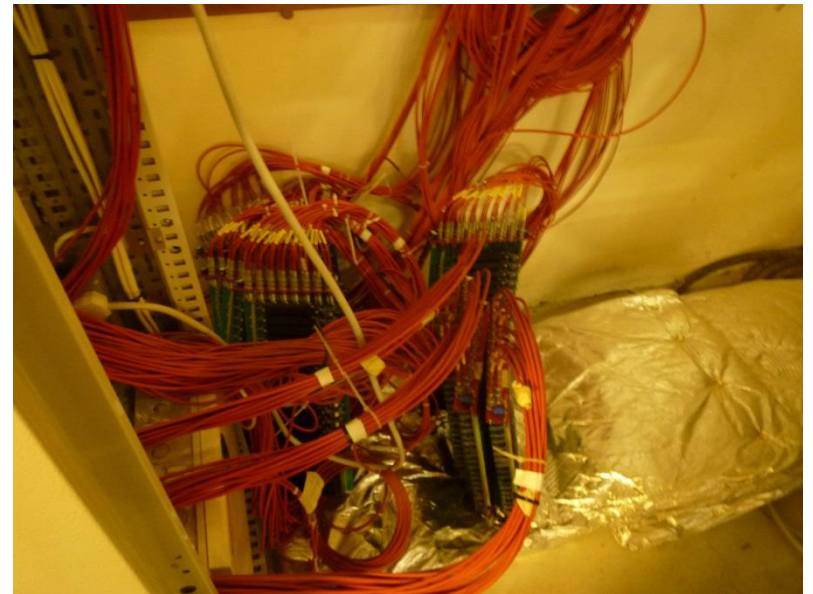
- TOF and KL share a common HV system based on a SY527 crate
- Some minor problems were pointed out by the MOM
- An intervention was done at the beginning of this week to clean up the crate and eventually change the air fans (R. Bertoni, M. Capponi, A. Iacofano)  now things are OK



# SY527 HV crate refurbishing



dusty inside



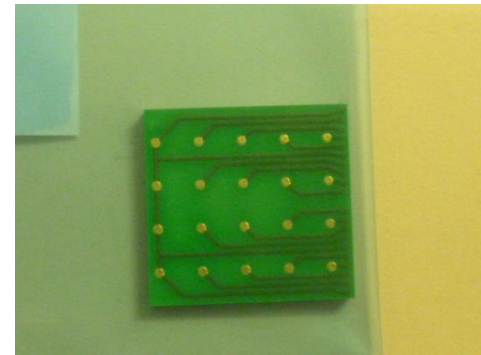
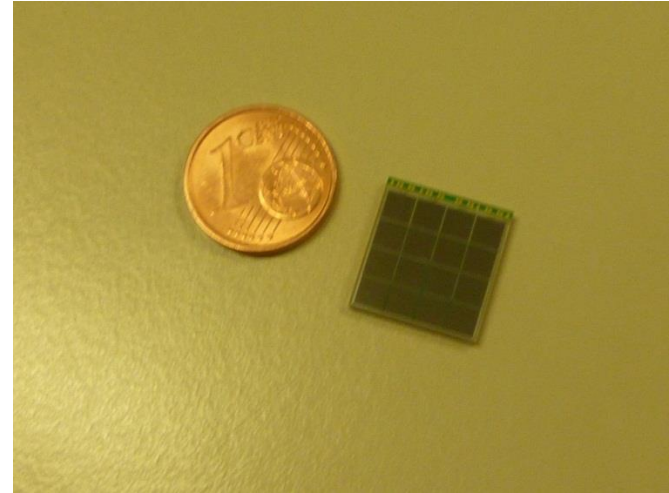
## 2. A backup solution for TOFes

- We were seriously concerned with the level of stray magnetic fields in the MICE Hall: bigger than foreseen by GG/JC/... ??
- Study a straight backup solution for present TOF stations, in case of problems : with SiPMT arrays readout (not sensitive to B fields up to few Tesla) replacing conventional PMTs (R4998)
- **Idea:** just use 2 SiPMT arrays instead of 2 PMTs with the same TOF mechanics layout, lightguides ...



# SiPMT arrays used

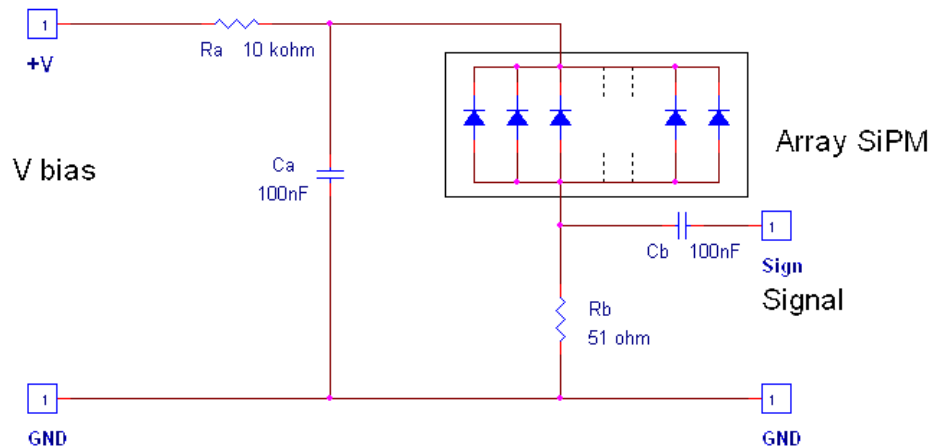
- Use 4x4 arrays of SiPMT 3x3 mm<sup>2</sup> (SenSL, Hamamatsu) or 4x4 mm<sup>2</sup> (FBK/IRST) to study if it is possible to replace 1" PMTS
- Preliminary studies with our test laser setup and cosmics
- Effort MIB+PV (M.Bonesini, R. Bertoni, G. Stringhini, A. deBari, M. Prata, M. Rossella, R.Nardo')



# Readout chain for SiPMT arrays

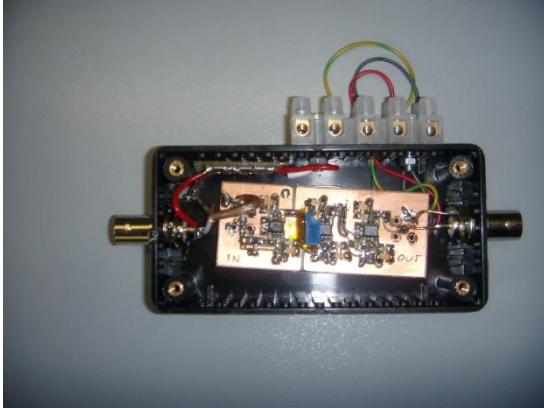


- SiPMT array custom mount
- 16 macrocells signals are summed up in the basette and then amplified



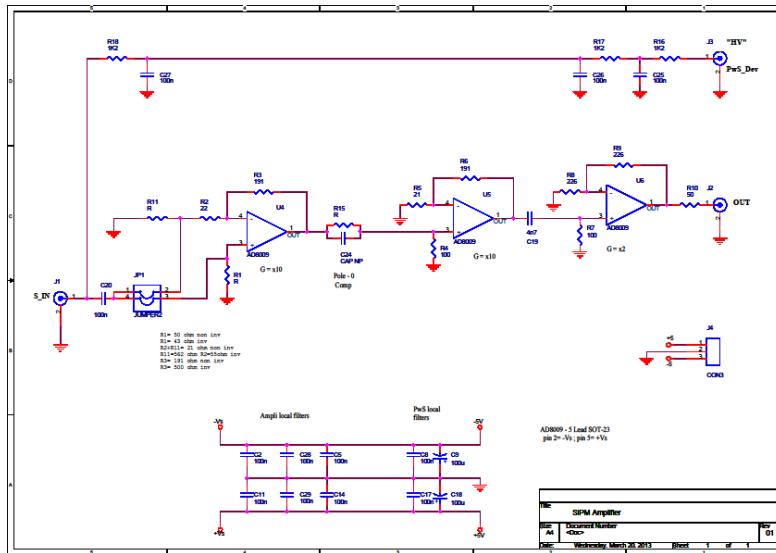
Schematic of one  
``basette''

# Custom amplifier

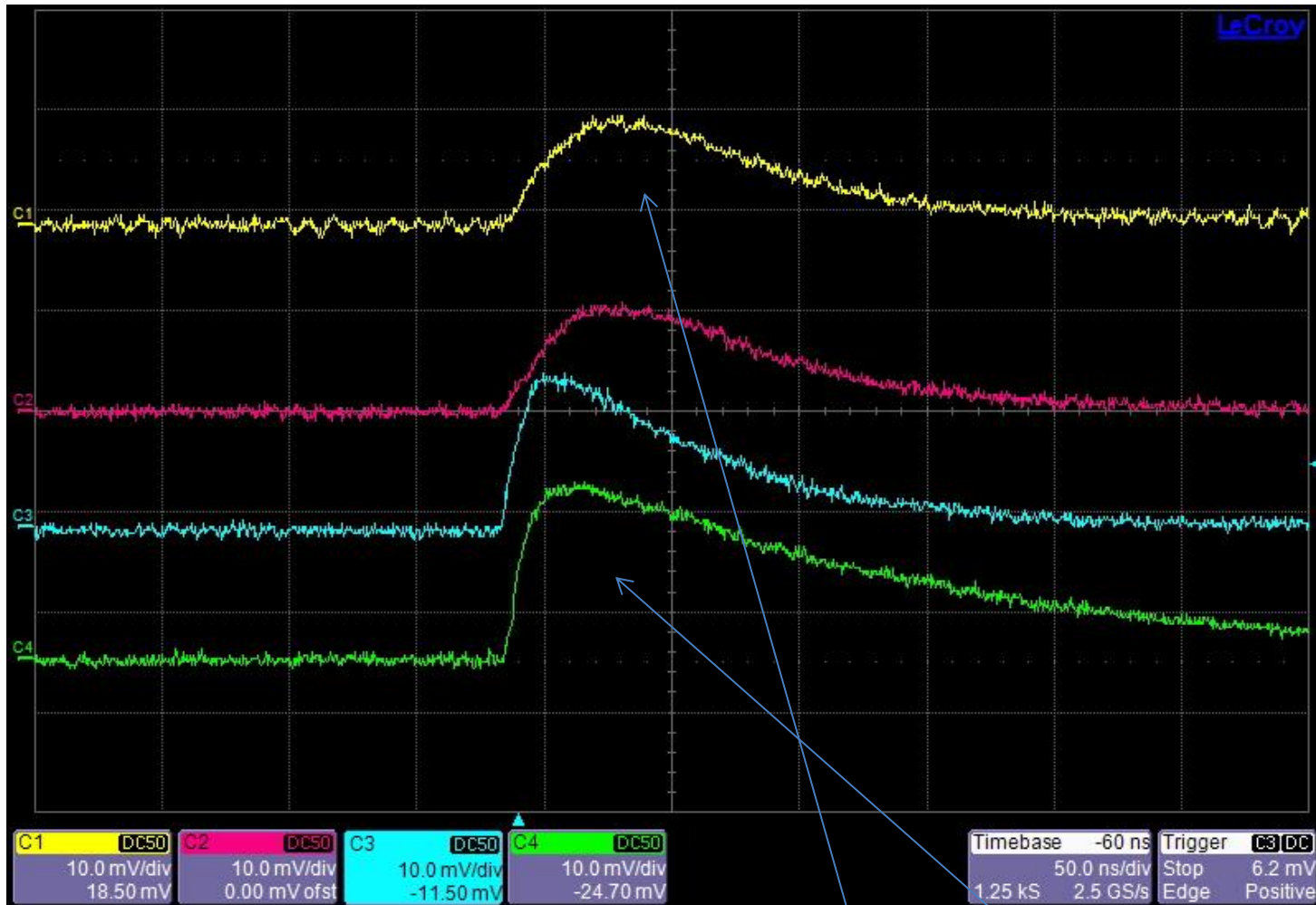


## Amplifier:

- Custom made (INFN Pv)
- 1 or 2 channels
- Gain up to 100X (30X with pole zero suppression)
- Input dynamic range: 0-70 mV
- Bandwidth : 600 MHz

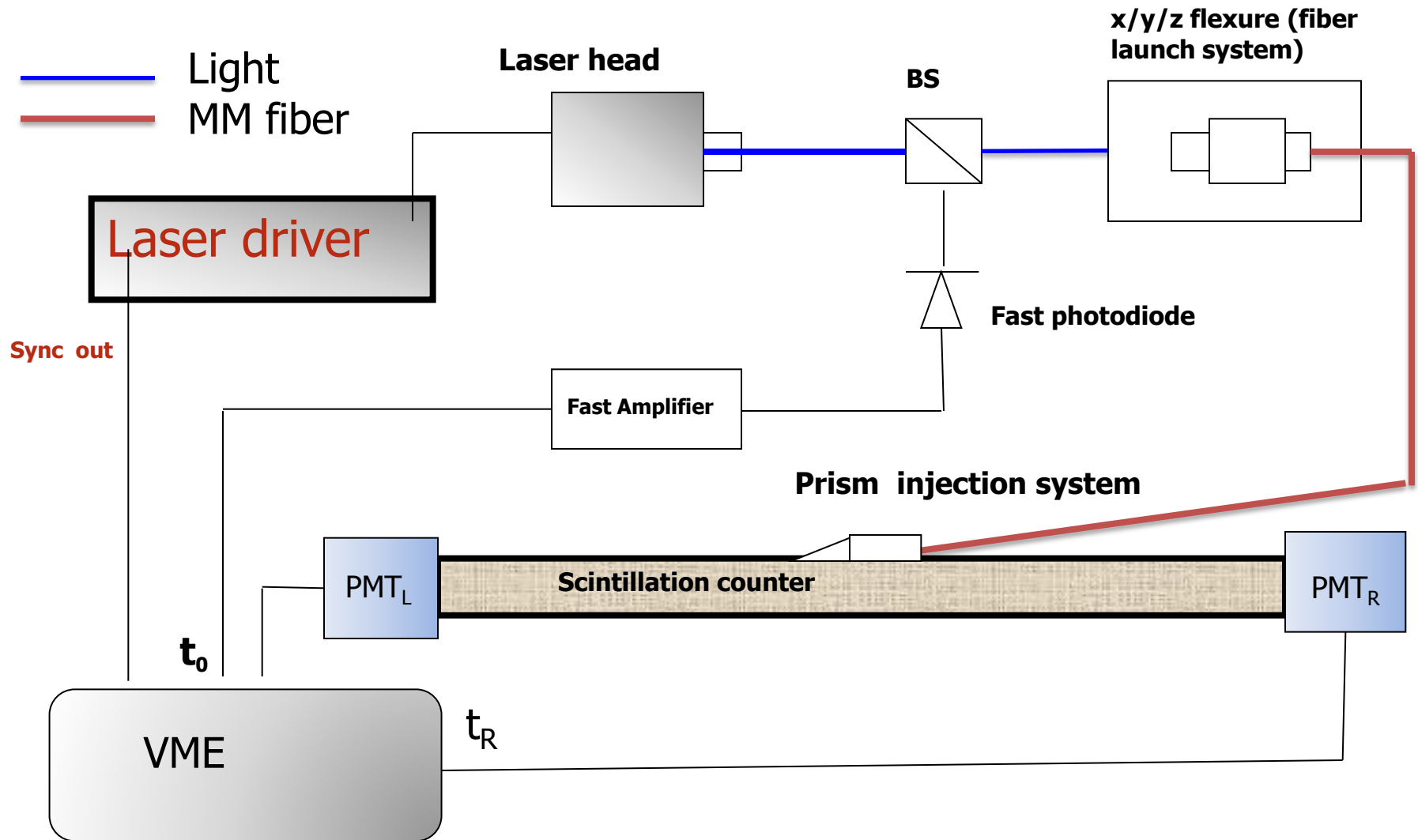






2 crossed bars equipped with SenSL or Hammamatsu SiPMT arrays, trigger on cosmics

# Experimental lab setup



# Test setup: home-made laser system

TYPICAL AVO-9B-C SYSTEM, FOR A 9 mm TO-18 LASER DIODE

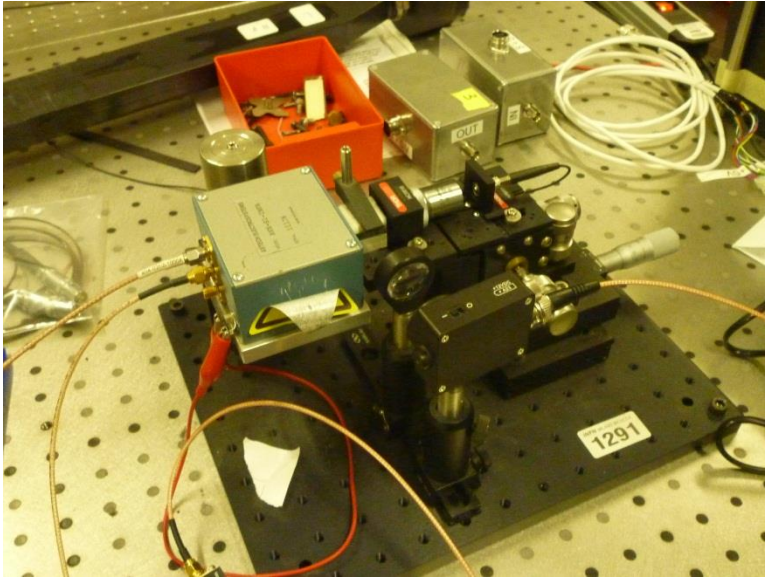


1. Fast Avtech AVO pulser + Nichia violet laser diode ( $\lambda \sim 408 \text{ nm}$ )
2. Laser pulses width selectable between 120 ps and 3 ns length, with a  $\sim 200 \text{ ps}$  risetime (simulate scintillator response)
3. Laser pulse height selectable to give scintillator response between a fraction of MIP and 10-50 MIPS
4. Laser repetition rate selectable between  $\sim 100 \text{ Hz}$  and 1 MHz
5. The laser beam is splitted by a 50% beamsplitter to give a reference  $t_0$  on a fast photodiode (Thorlabs DET10A risetime  $\sim 1 \text{ ns}$ ) amplified via a CAEN A1423 wideband inverting fast amplifier (up to 51 dB,  $\sim 1.5 \text{ GHz}$  bandwidth)

		SPECIFICATIONS					AVO-9 SERIES	
<b>Module 1.1 Amp. with PWP 1.1 MIP</b>								
Model	AVO-9A-EP	AVO-9B-EP	AVO-9E1-EP	AVO-9E2-EP	AVO-9A3-EP	AVO-9A4-EP	AVO-9A5-EP	
Amplitude <sup>1)</sup>	0 - 200 mA	0 - 200 mA	0 - 200 mA	0 - 400 mA	0 - 600 mA	0 - 800 mA	0 - 1 A	
Max. output resistance (no DC Excess <sup>2)</sup> )	15V	15V	15V	25V	40V	40V	55V	
$R_L + R_{ext}$	50V							
Transfer ratio, H <sub>1</sub>	1							
Allowed load voltage range <sup>3)</sup>	0 to 2V. (Contact Avtech if your diode has a higher forward voltage drop)							
Pulse width (FWHM)	0.4 - 4 ns	0.5 - 100 ns	0.5 - 1000 ns	0.6 - 1000 ns	0.4 - 2 ns (50% <sup>4)</sup>	1 - 10 ns	1 - 10 ns	
Minimum duty cycle	5%	5%	5%	5%	5%	5%	5%	
Maximum PDP <sup>5)</sup>	1 MW	1 MW	100 MW	1 MW	100 MW	1 MW	1 MW	
Rise time (20% - 80%)	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	
Fall time (80% - 20%)	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	$\leq 200 \text{ ps}$	
Related IEC series:	AVP-9A-1	AVMP-2	AVPP-1A	AVPP-2A	AVP-9A-1	AVP-9A-1	AVP-9A-1	
Included output module:	AVO-9C							
Polarity:	Positive or negative (specify)							
(PDP) and/or I-210 control <sup>6)</sup>	Standard on 40 units.							
Lithium driver:	Check <a href="http://www.avtech.com/links">http://www.avtech.com/links</a> for availability and downloads							
Notes / Misc. comment <sup>7)</sup>	Optional. See <a href="http://www.avtech.com/links">http://www.avtech.com/links</a> for details							
Double pulse separation (specify)	0 to +50% of the period	Not available	0 to +50% of the period	NA	0 to +50% of the period	NA	NA	
Propagation delay	$\leq 100 \text{ ns}$ (0 to 10 ns to pulse out)							
jitter	$\pm 20 \text{ ps} \pm 0.01\%$ of sync delay (0 to 10 ns to pulse out)							
DC offset or bias insertion:	Apply required DC bias current in the range of 0 to 100 mA solder terminal on output module.							
Sync delay	Variable 0 to 200 ns (1 second for 40 units), sync out to pulse out							
Sync output (to IEC):	$\pm 2V$ , 500 ns							
Stim input:	Synchronous or asynchronous, active high or low, invertable. Suppresses triggering when active.							
Trigger required:	Built-in mode: $+5 \text{ V (TTL)}$ , $\geq 50 \text{ ns}$							
Monitor output option <sup>8)</sup>	Provides connection to output of photo diode detector.							
Connectors:	Out: 0.5" BNC	User-specified socket. Sockets can be provided for 9.5 mm, 9 mm, butterfly, and other packages. Typ. Spec. 0.5" BNC, Monitor SMA						
Recommended accessory kit:	Add the suffix "ACT" to the model number to include the recommended accessory kit. Consists of three SMA, 18 Ohm, 2 Watt attenuators (10, 20 & 30 dB) for use on the output, and one 50 Ohm, 1 Ohm, 1 Watt load through terminator (10W SMA, 0.5" BNC) for use on external trigger inputs.							
Power requirements:	100 - 240 VAC, 30 - 80 W							
Dimensions, Mainframe (90-900):	100 x 400 x 270 mm (3.9" x 15.7" x 10.6"). Anodized aluminum, with blue plastic trim.							
Dimensions, Output Module:	41 x 66 x 76 mm (1.6" x 2.6" x 3.0"). cast aluminum, blue painted							
Temperature range:	$+15^\circ\text{C}$ to $+45^\circ\text{C}$							

1) All multi-module (AVO-9E1-EP) and P1-210 models of amplified and assembly. See <http://www.avtech.com/links> for details.  
2) Excess current is not allowed. Excess current will result in damage to the device. Excess current will result in damage to the device. Excess current will result in damage to the device.  
3) For operation at maximum output power, the load must be matched to the output impedance of the device. Excess current will result in damage to the device. Excess current will result in damage to the device.  
4) The rise time is measured at 50% of the pulse height. Excess current will result in damage to the device. Excess current will result in damage to the device.  
5) The PDP is the product of the pulse width and the pulse height. Excess current will result in damage to the device. Excess current will result in damage to the device.  
6) The I-210 is a 210 MHz wideband inverting fast amplifier. Excess current will result in damage to the device. Excess current will result in damage to the device.  
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# Some details



## Laser injection system:

- Newport 20X microscope objective
- x/y/z Thorlabs micrometric flexure system



## Acquisition system:

- VME based (CAEN V2718 interface)
- VME CAEN TDC V1290A (25 ps res)
- VME CAEN QADC V792
- VME CAEN V895 L.E. discriminator (typ discr values -50 -100 mV)
- home-written acquisition software

# Tuning of laser setup

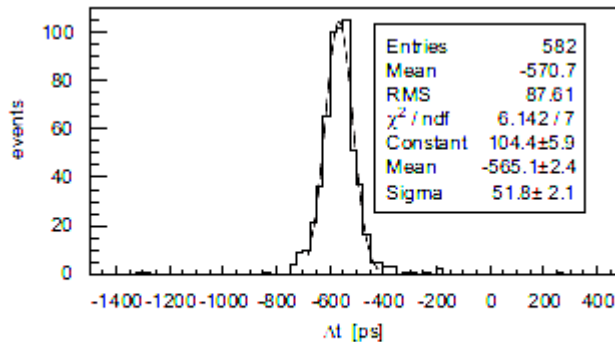


Fig. 12.  $(t_r - t_k)/2$  distribution from a BC404 bar specimen and beam impact point at  $x = 20$  cm (counter center).

Table 2

Intrinsic resolution of counters made of scintillation bars of 4 or 6 cm width and with lightguides made of different materials and/or of different shape (Winston cone or fishtail).

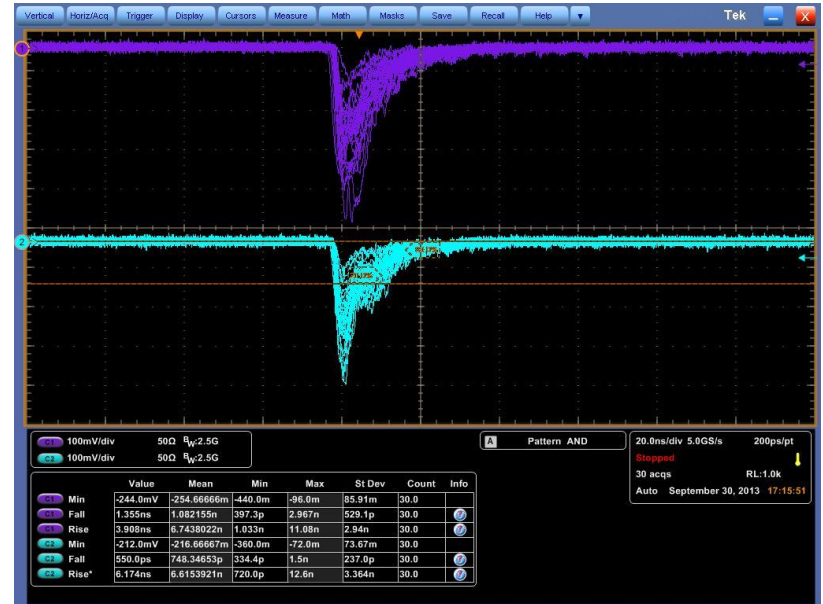
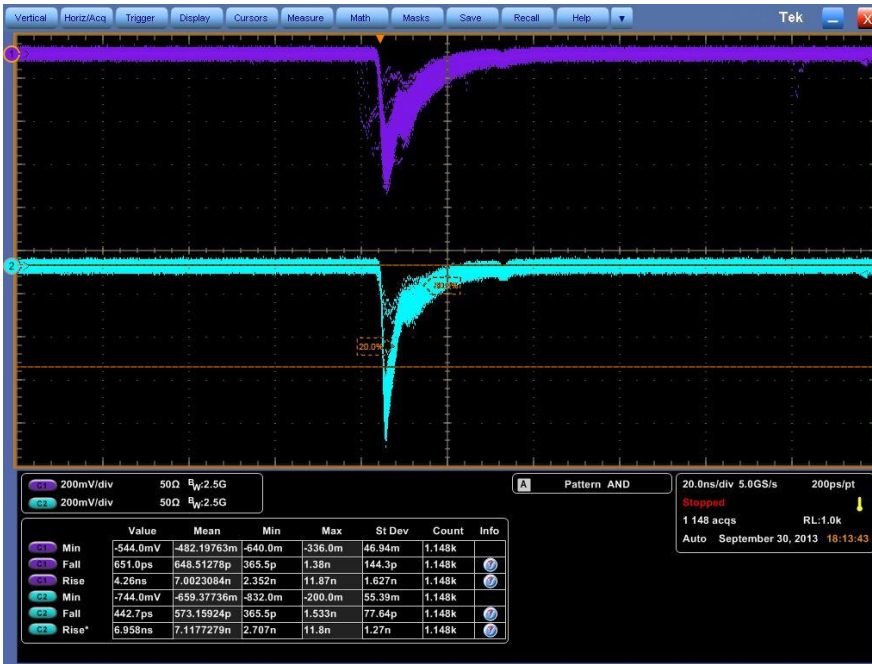
Counter type	$\sigma_t$ (ps)
UPS95F 4 cm bar Winston Cone	$56 \pm 2$
UPS95F 4 cm bar REPSOL UVT lightguide	$50 \pm 8$
BC404 6 cm bar REPSOL UVT lightguide	$46 \pm 5$
BC420 6 cm bar REPSOL UVT lightguide	$45 \pm 1$
BC408 6 cm bar PERSPEX UVA lightguide	$60 \pm 2$

From R. Bertoni et al., NIM A615 (2010) 14

- Tune laser settings to reproduce testbeam results ( $\sigma_t$ ) with a single counter equipped with R4998 PMTs and MIP response
- Study single counter response substituting PMTS readout with SiPMT arrays readout
- Advantage as respect to cosmics is the possibility to collect a high statistics in a short time, with different exp conditions (amplifier tuning, ...)

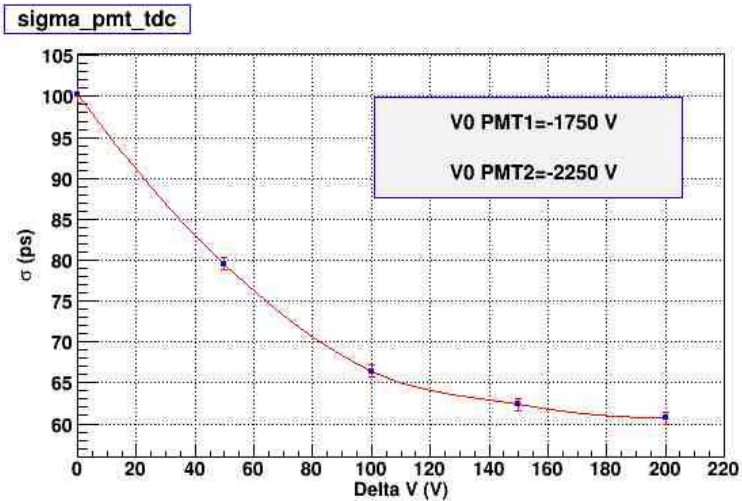
BC 404 scintillation counter (60 cm long, 6 cm wide) equipped with Hamamatsu R4998 PMTs (as in MICE expt)

PMT signals with laser

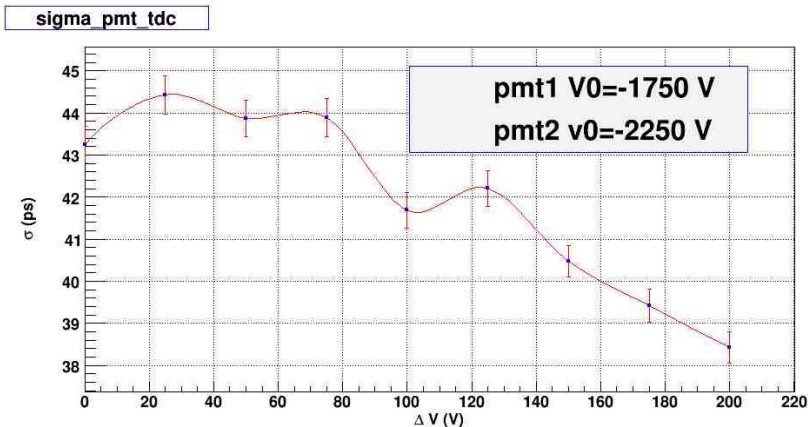


PMT signals with cosmics

# Results with conventional PMTs (as benchmark)



Very low laser light intensity  
(1 MIP or less)

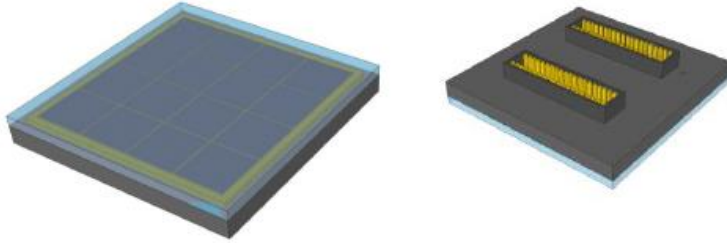


Standard laser light intensity  
(2-3 MIP)

$$V_{op} = V_0 + \Delta V$$

# Results with FBK/IRST arrays

## ASD-SiPM3S-P-4X4A



4×4 SiPM Array

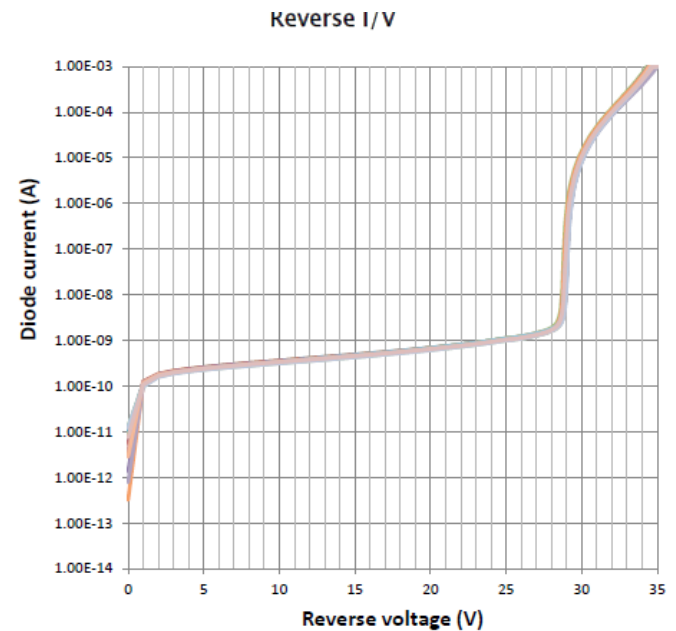
3 mm pixel pitch

2.95x2.95 mm<sup>2</sup> SiPMs  
50 μm gap between SiPMs

Material: FR4 +  
transparent epoxy layer

AVX 5602-040 series  
plug connectors

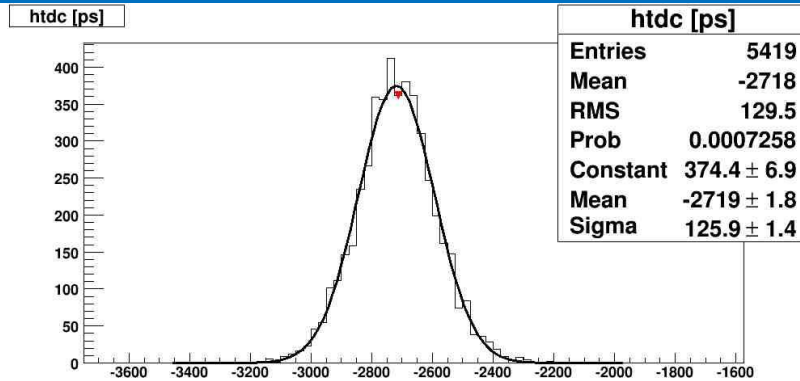
Receptacles included  
(AVX 5602-040 series)



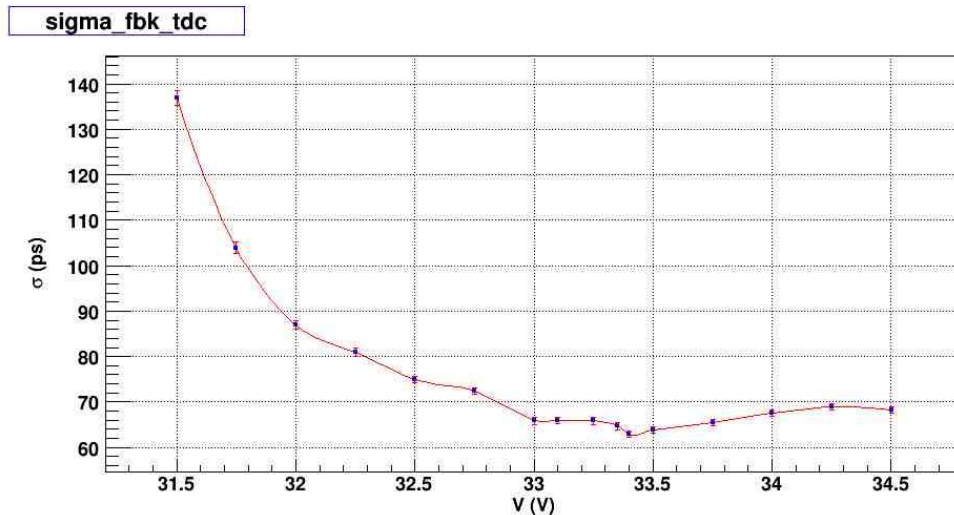
SiPMT I-V characteristics  
(manufacture specs)



# Results with FBK/IRST SiPMT arrays



Typical difference  $\Delta TDC$   
(converted in ps) :  $\sigma_t = \sigma_{\Delta TDC} / 2$

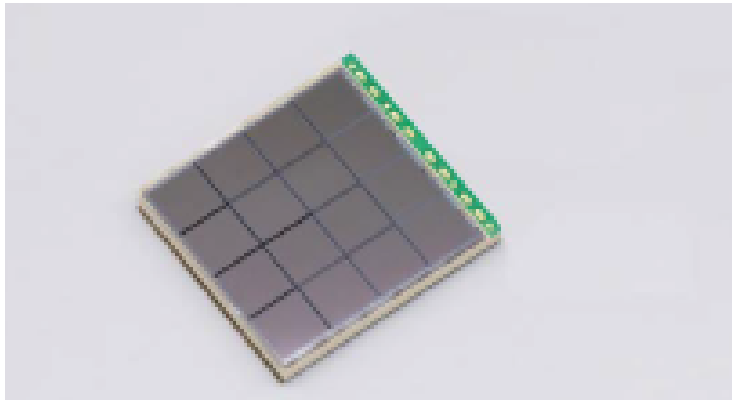


Standard light intensity

$\sigma_t \sim 60$  ps at best, but  
RGB array !!

Vop

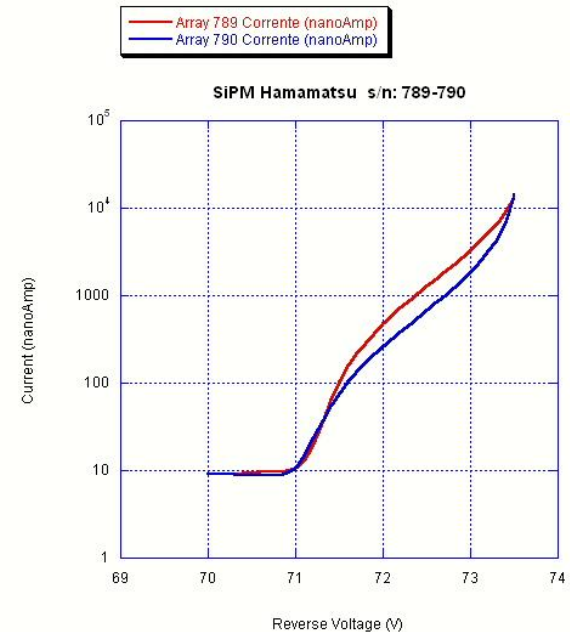
# Results with Hamamatsu S11828-3344 Arrays



**Monolithic MPPC array in SMD package  
S11828-3344M**

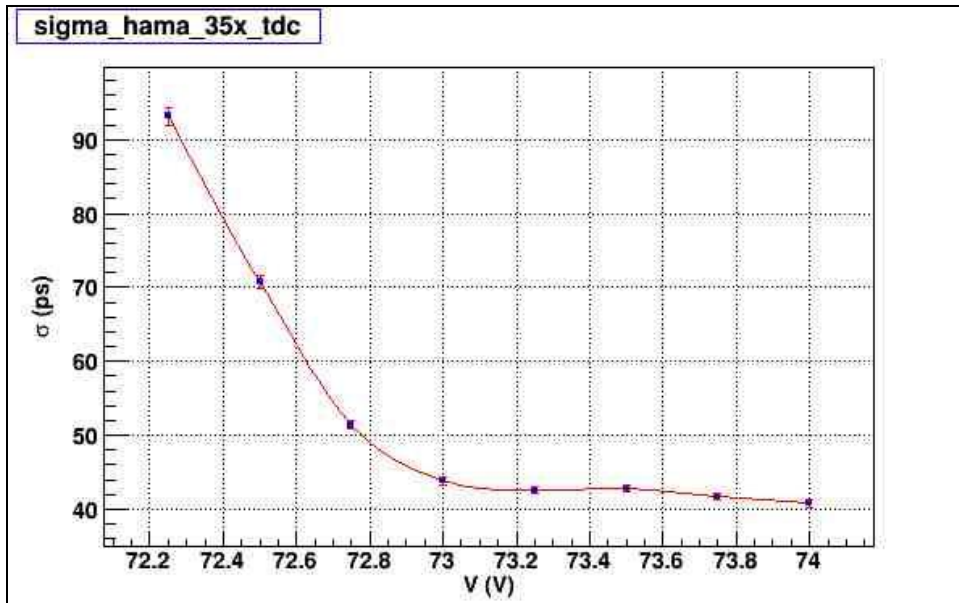
## Features

- Monolithic array: 16 ch (4 × 4 array)
- Nonmagnetic package
- Effective active area: 3 × 3 mm/ch
- Pixel pitch: 50  $\mu$ m
- Allows multiple devices to be arranged in a buttable format



SiPMT I-V characterisation  
(our characterisation)

# Results with Hamamatsu S11828 Arrays



Standard light intensity

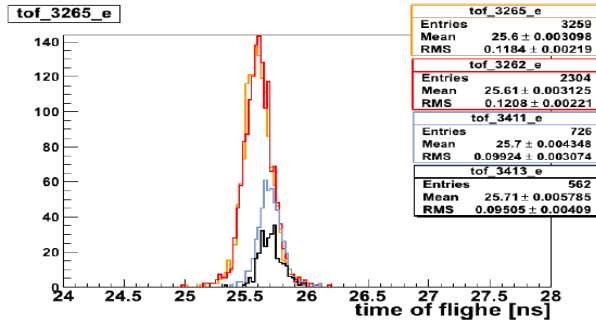
We foresee soon tests with Hamamatsu S12642 arrays, TSV package, where better results may be expected

# Preliminary conclusions

- SiPMT arrays may be a good replacement for fast PMTs in scintillator time-of-flight system
- Preliminary conclusions show a “comparable” timing resolution with fast PMTs
- Clearly results must be validated by testbeam (one at BTF is foreseen)
- Some optimization may be needed: use of fast ( $> 1$  GHz) amplifiers, NUV SiPMT arrays (instead of RGB ones) to better match scintillator emission

# 3. Rate effects in TOF: again ...

$e^+e^-$  puzzle.

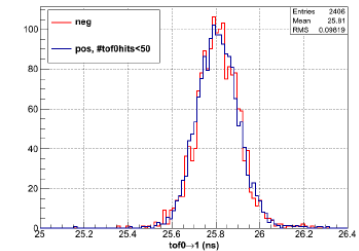
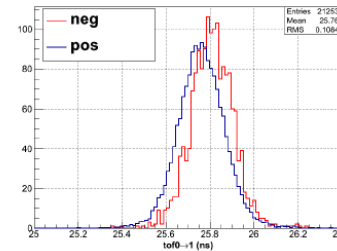


Some rate effects have been seen, but source is unclear: may be anything from PMTs to TDCs to splitters/shapers ... beam ...

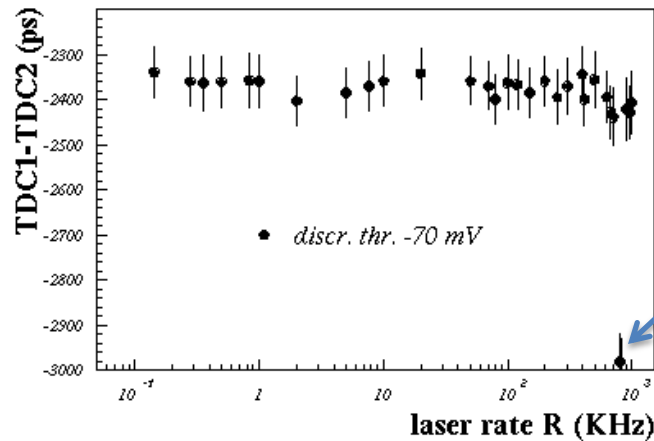
- The variation of the number of particle trigger per spill introduces difference in the measured time-of-flight ( $\sim 100$  ps) even when we use identical settings of the beamline channel.



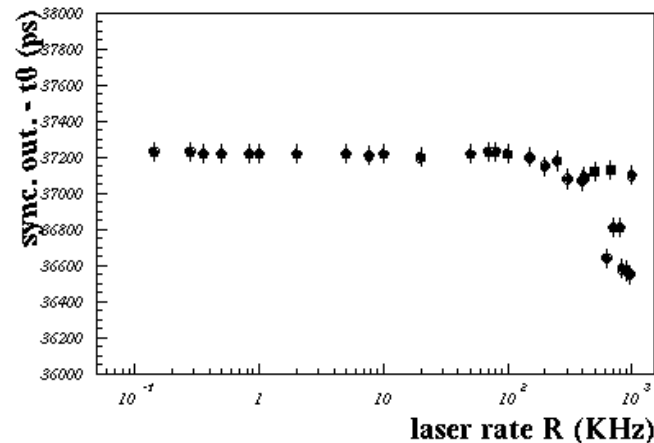
- First looked at the time of flight for + and - data.
- Left: Obvious shift:  $e^+$  have lower tof than  $e^-$ .
- Right: No difference when only lower hit rate + data is selected



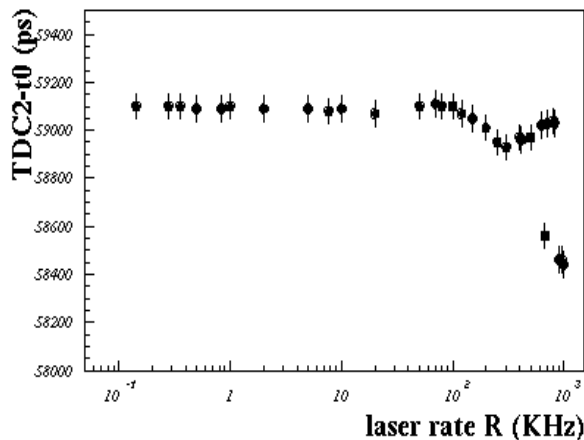
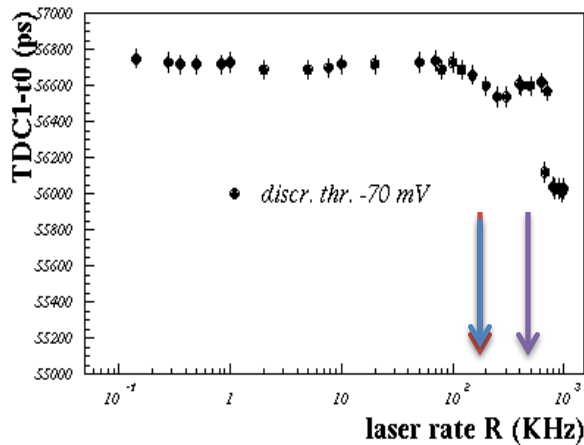
# February results for TDC



This glitch prompted our attention and the need for an external  $t_0$



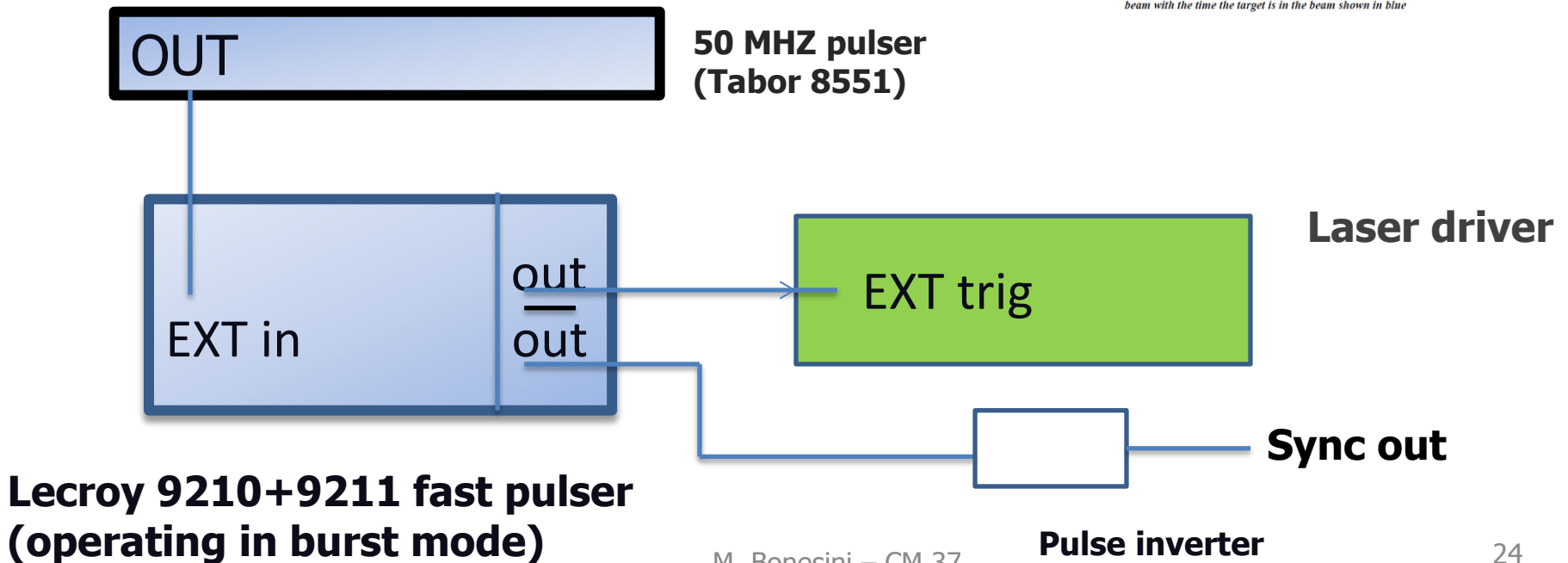
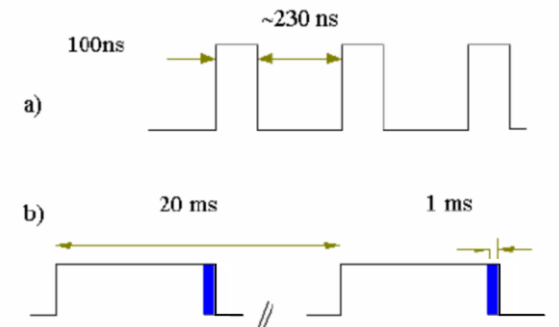
# February results: TDC vs t0



- Some clear effects appear at very high rates > 500 KHz for single PMTs with a -70 mV thr on V895 discri. (results move of about 600 ps) with some hints at lower values (rates > 150 KHz)

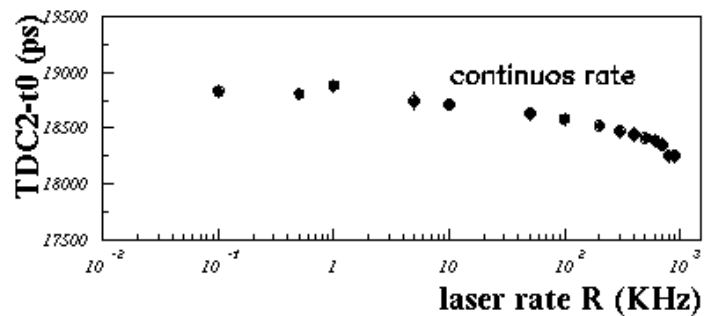
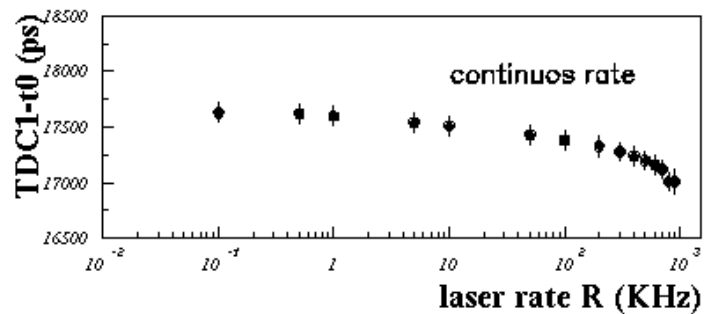
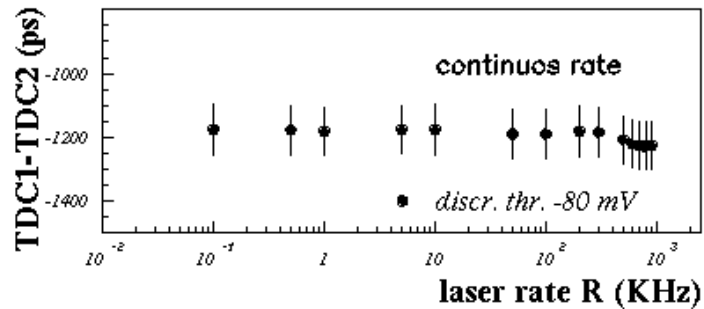
# New results:

- We simulated the ISIS cycle and checked how results change vs a continuous pulsing

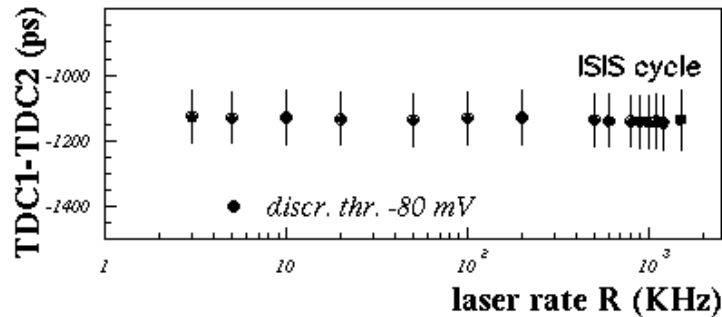




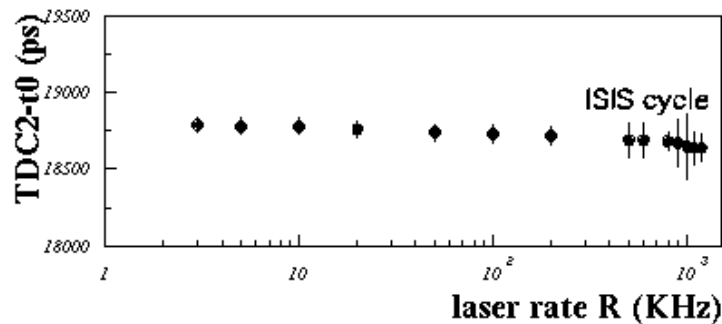
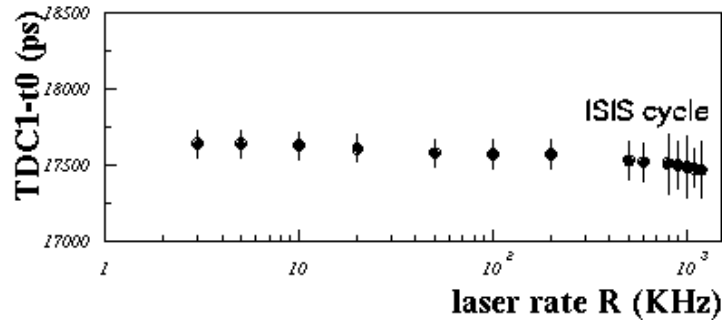
# TDC vs $t_0$ : continuous pulsing



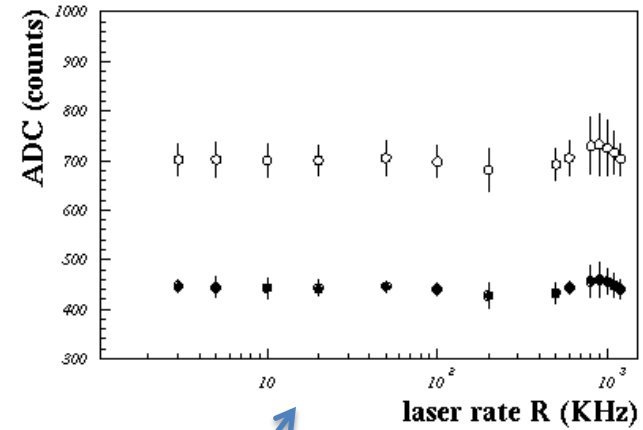
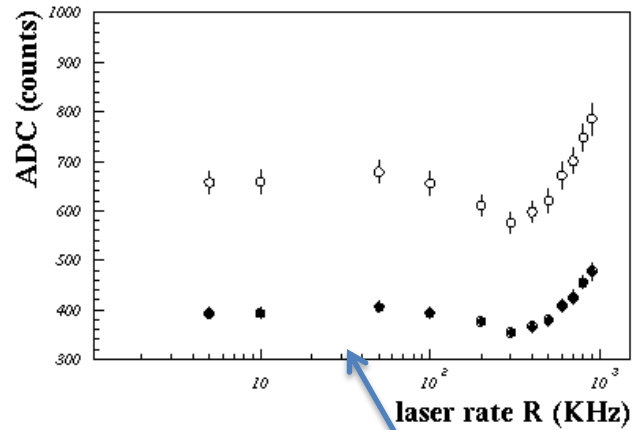
# TDC vs $t_0$ : ISIS cycle



An ISIS-like cycling reduce the impact of rate effects



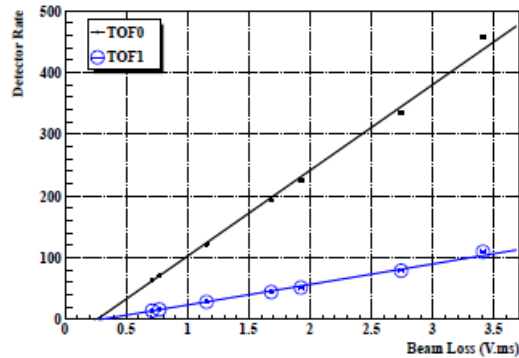
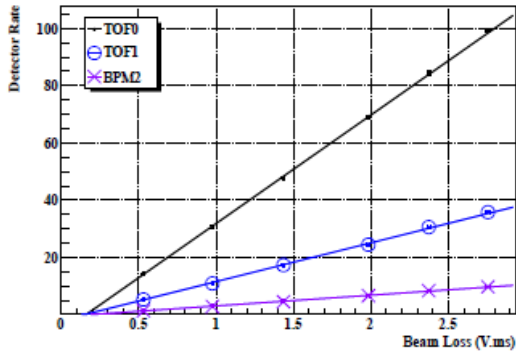
# ADC vs rate



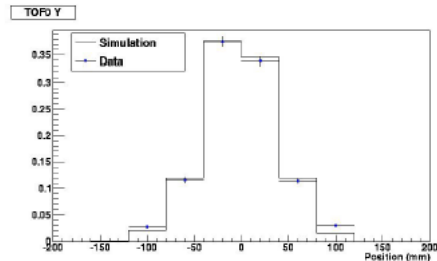
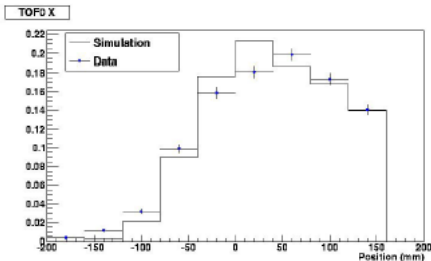
Continuous pulsing

ISIS-like pulsing

# It is really a problem ?



## Particle rate vs target dip



## Beam profile at TOF0

## From JINST paper

- Expected max rate at TOF0 for single slab for  $\mu^+(\mu^-)$ : **100 (30) part/spill\***  
**0.68/4slabs~18 (6) KHz (1 V activation):**  
**with 4V activation we may go to 75 KHz**
- **A factor 5 less in TOF1**
- From previous results OK up to 150-200 KHz

# Conclusions



## **My wise cat conclusions:**

- 1. Some effect seems to show up, albeit at higher rates than we experience**
- 2. The ISIS cycle structure contribute to reduce their impact**
- 3. The effect, if any, seems not to be connected to PMTs fatigue or VME TDCs**

